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Kondo

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(54) **FUEL INJECTION VALVE**

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B05B 1/30 (2006.01)

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See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

5,452,858 A * 9/1995 Tsuzuki et al. 239/533.8
5,979,803 A * 11/1999 Peters et al. 239/533.4
6,420,817 B1 7/2002 Ricci-Ottati et al.
6,425,368 B1 * 7/2002 Lambert 123/300
6,647,966 B2 * 11/2003 Tian et al. 123/467
7,455,244 B2 * 11/2008 Boecking 239/102.2
2007/0152084 A1 7/2007 Boecking

FOREIGN PATENT DOCUMENTS

JP 10-288116 10/1998

* cited by examiner

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(57) **ABSTRACT**

A fuel injection valve includes a body having a high pressure fuel passage and a nozzle hole, which is connected to the passage, a nozzle needle opening/closing the hole and having a needle piston part, a piezo stack extended when the stack is charged and contracted when the stack discharges electric charge, a cylinder, in which the needle piston part is slidably inserted and which is driven by the stack, a fixed piston having a fixed piston part that is slidably inserted in the cylinder and that has a larger diameter than the needle piston part, an oil-tight chamber between the needle piston part and the fixed piston part in the cylinder, and a nozzle spring urging the needle in a valve closing direction. The cylinder is displaced due to extension/contraction of the stack, so that volume of the chamber increases/decreases and the needle opens/closes the hole.

6 Claims, 7 Drawing Sheets

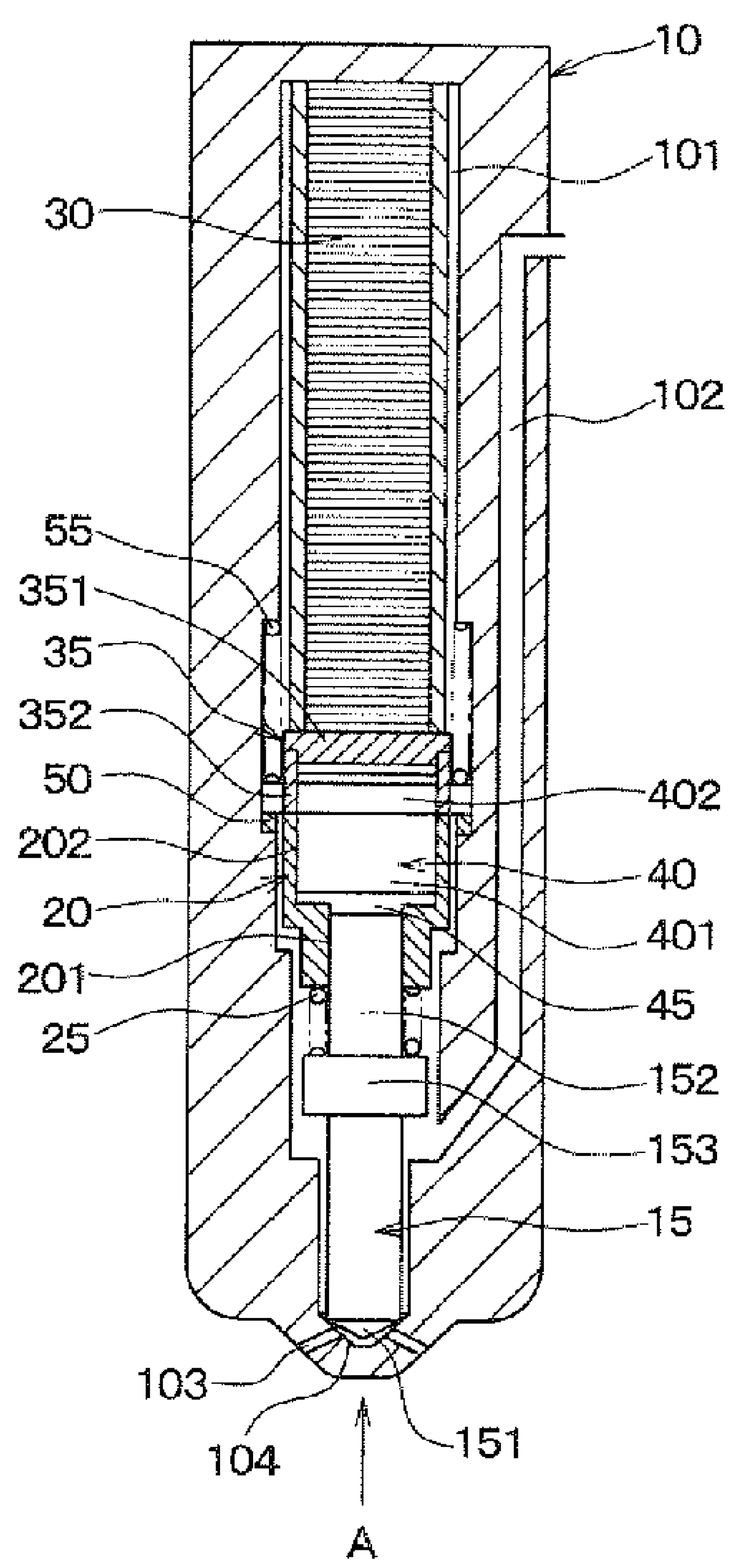

FIG. 1

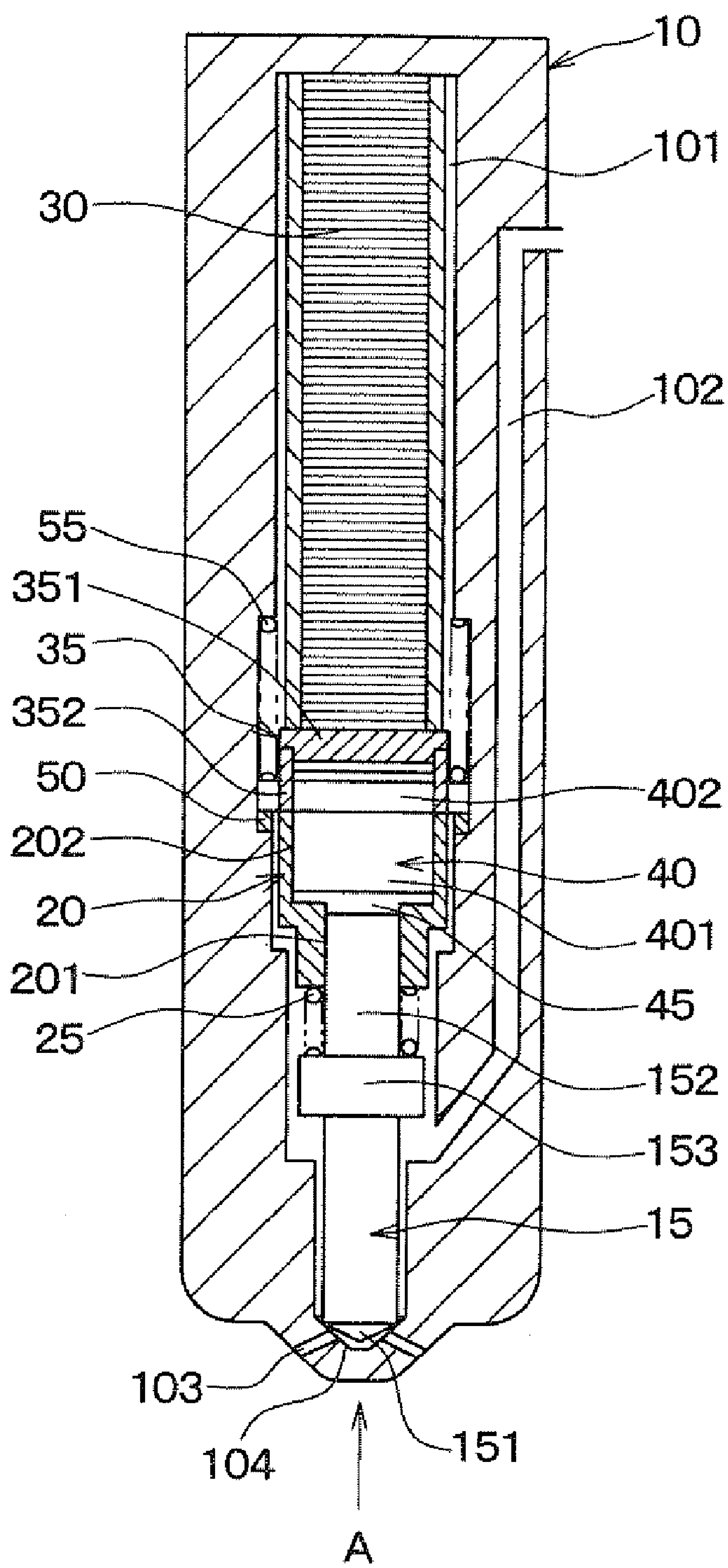
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FIG. 2

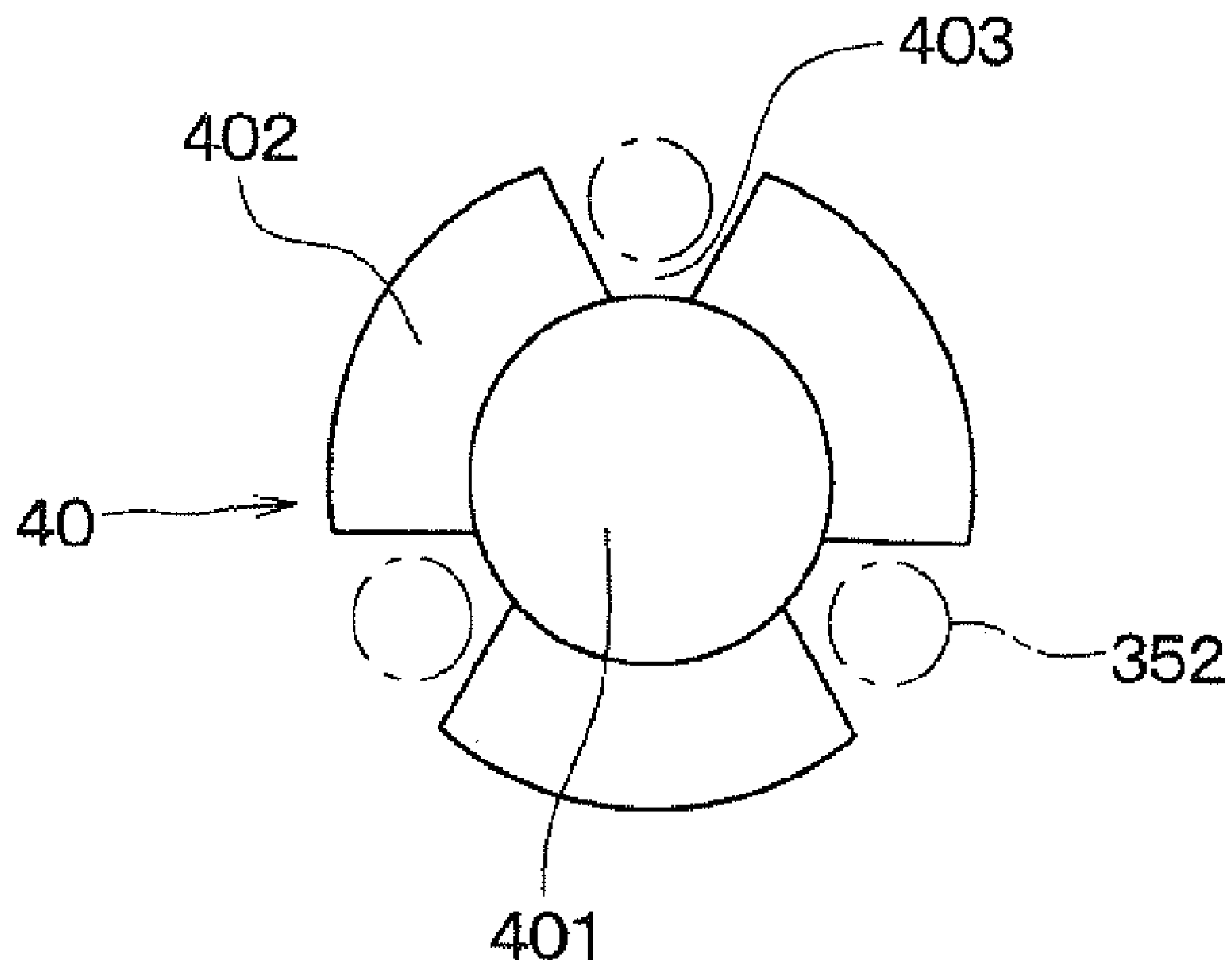

FIG. 3A

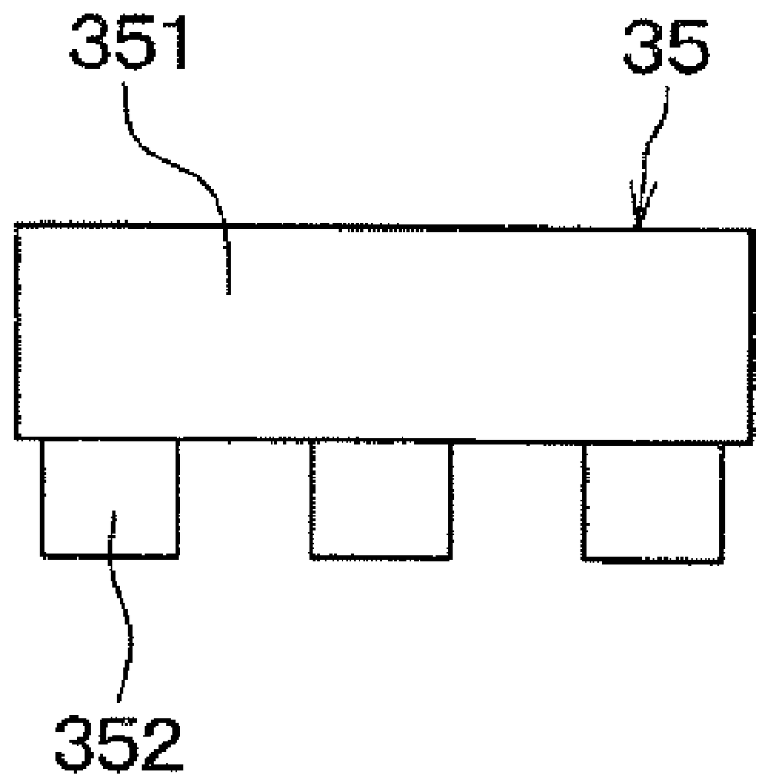

FIG. 3B

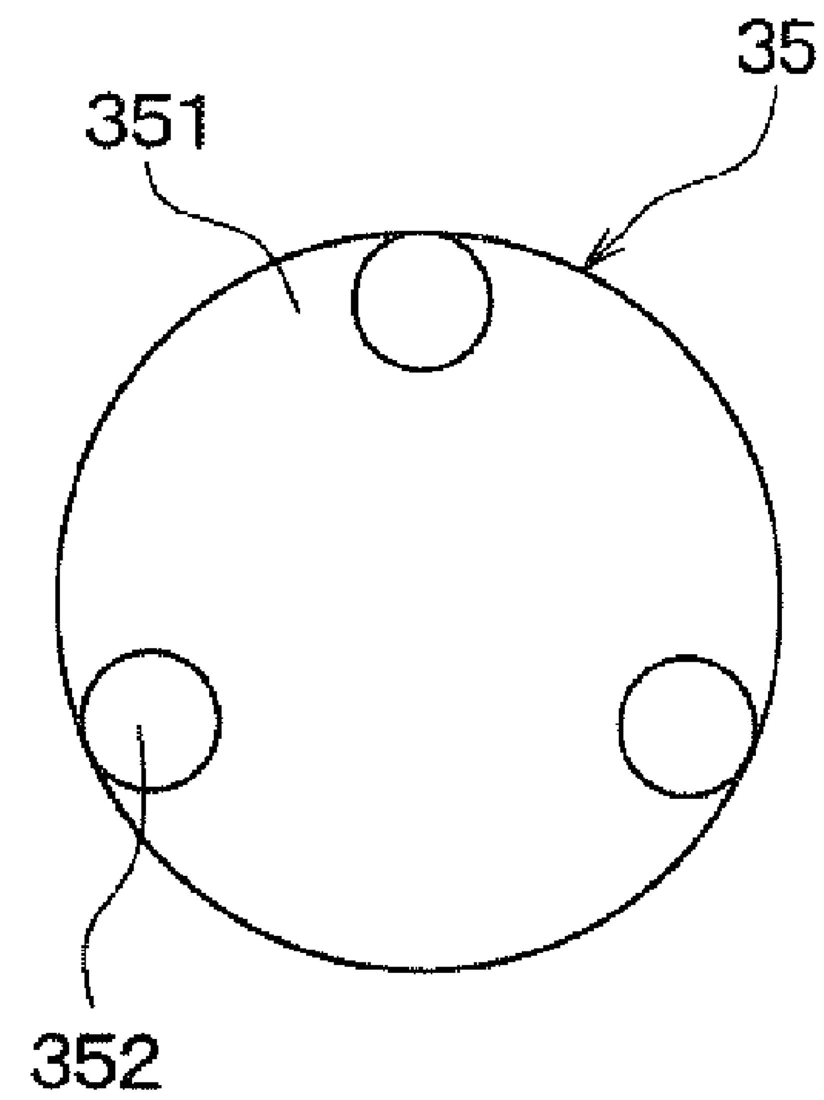

FIG. 4A

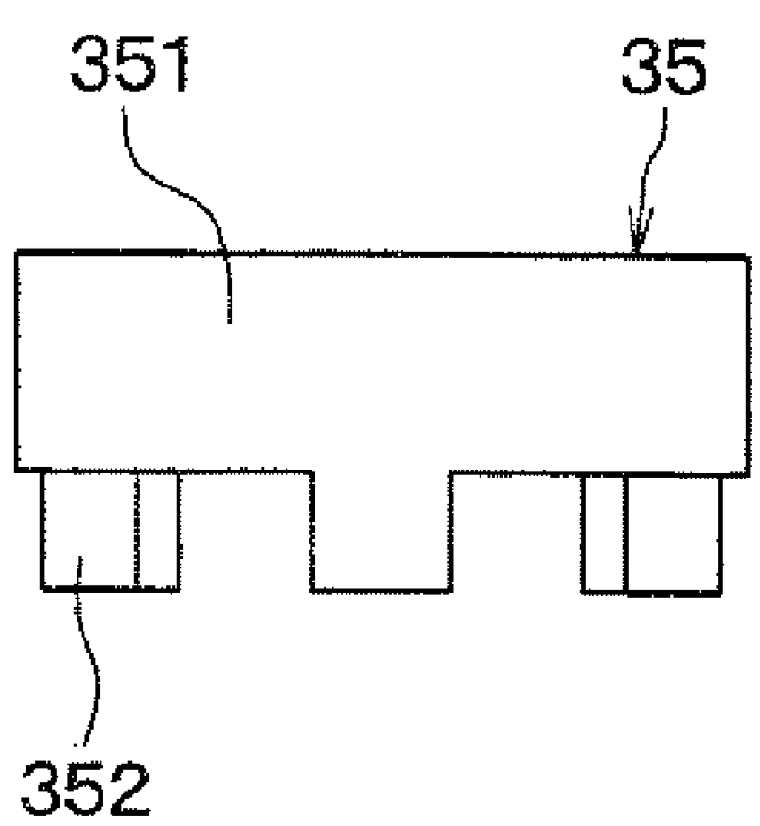

FIG. 4B

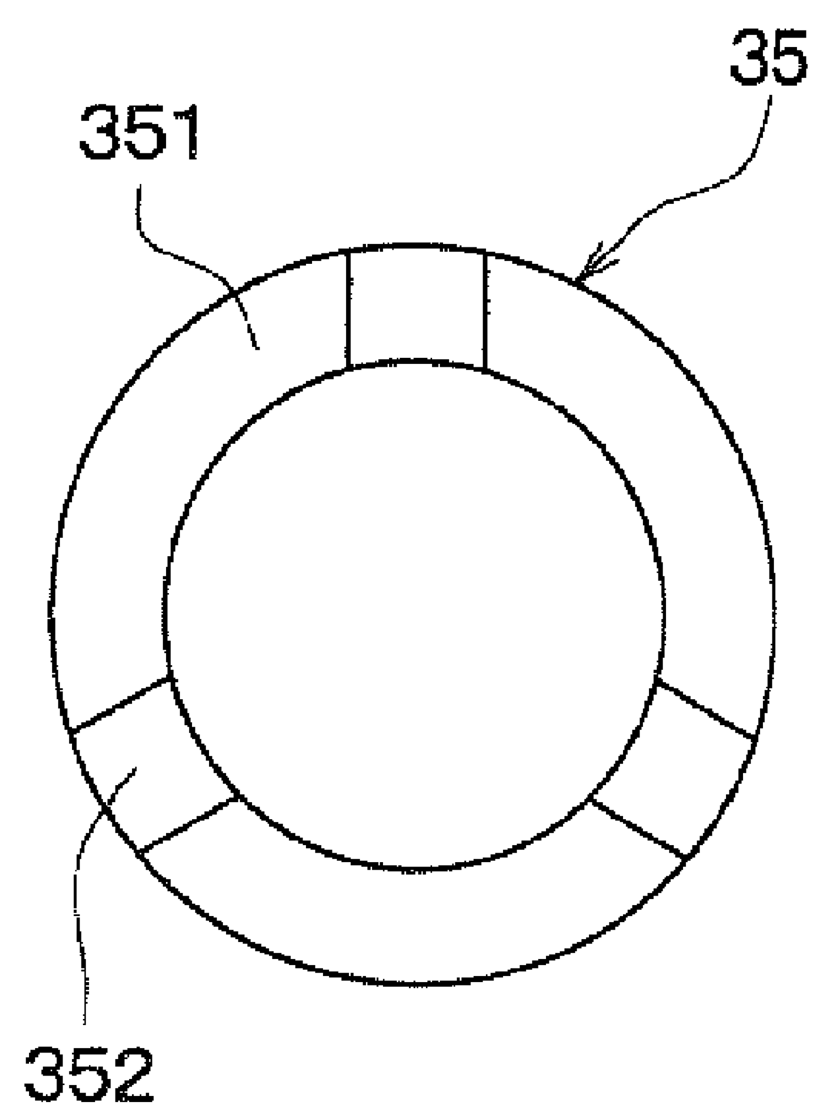

FIG. 5

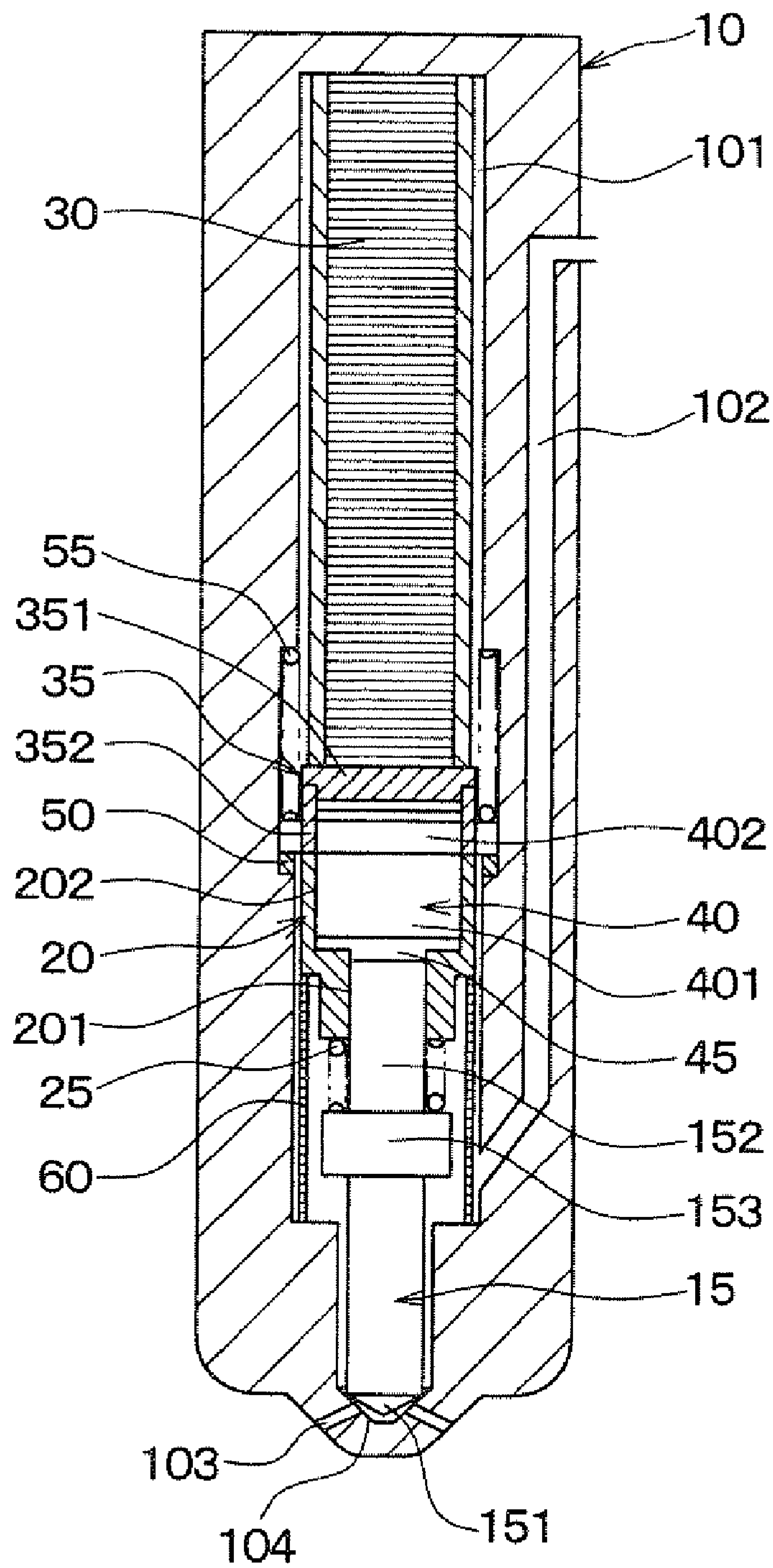
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FIG. 6A

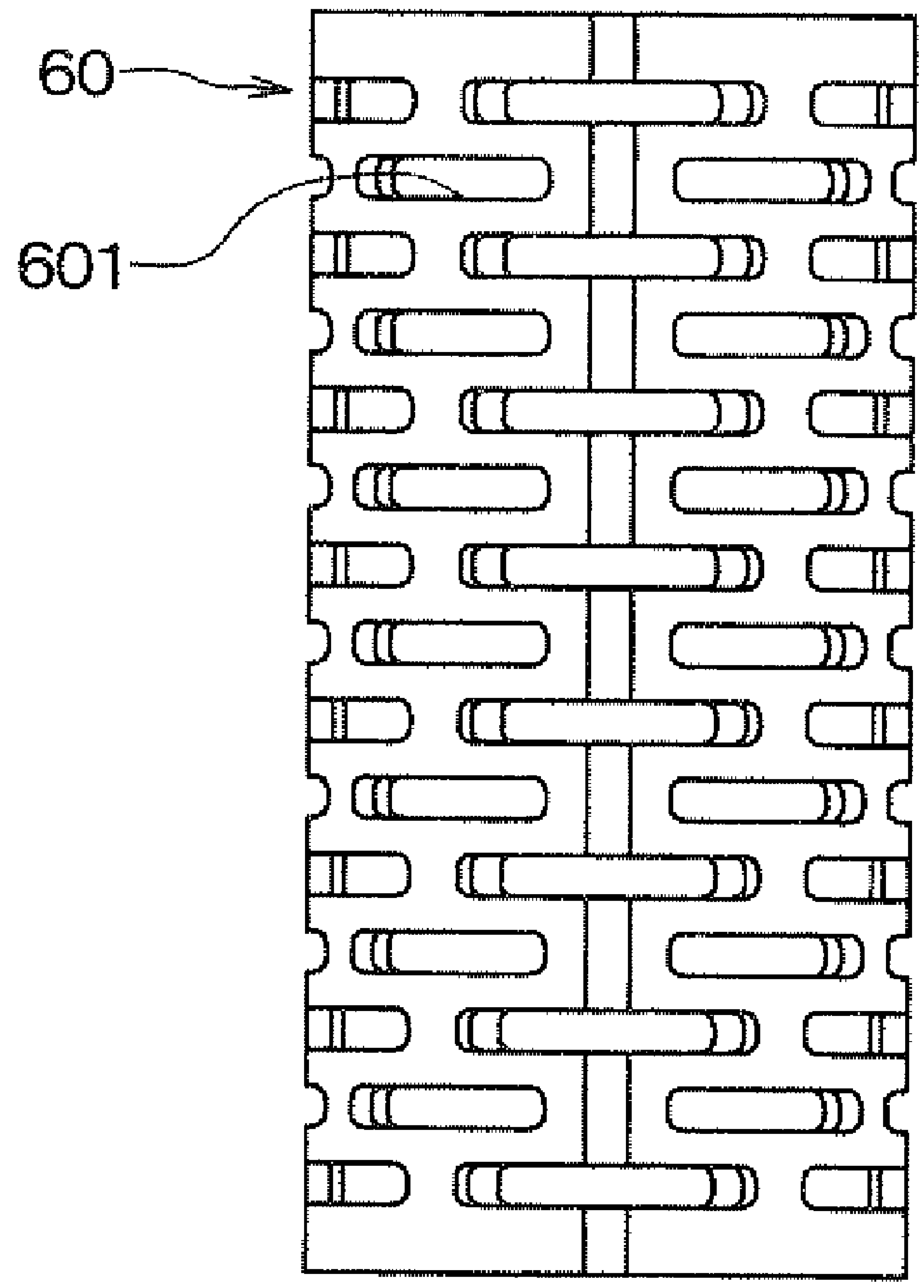

FIG. 6B

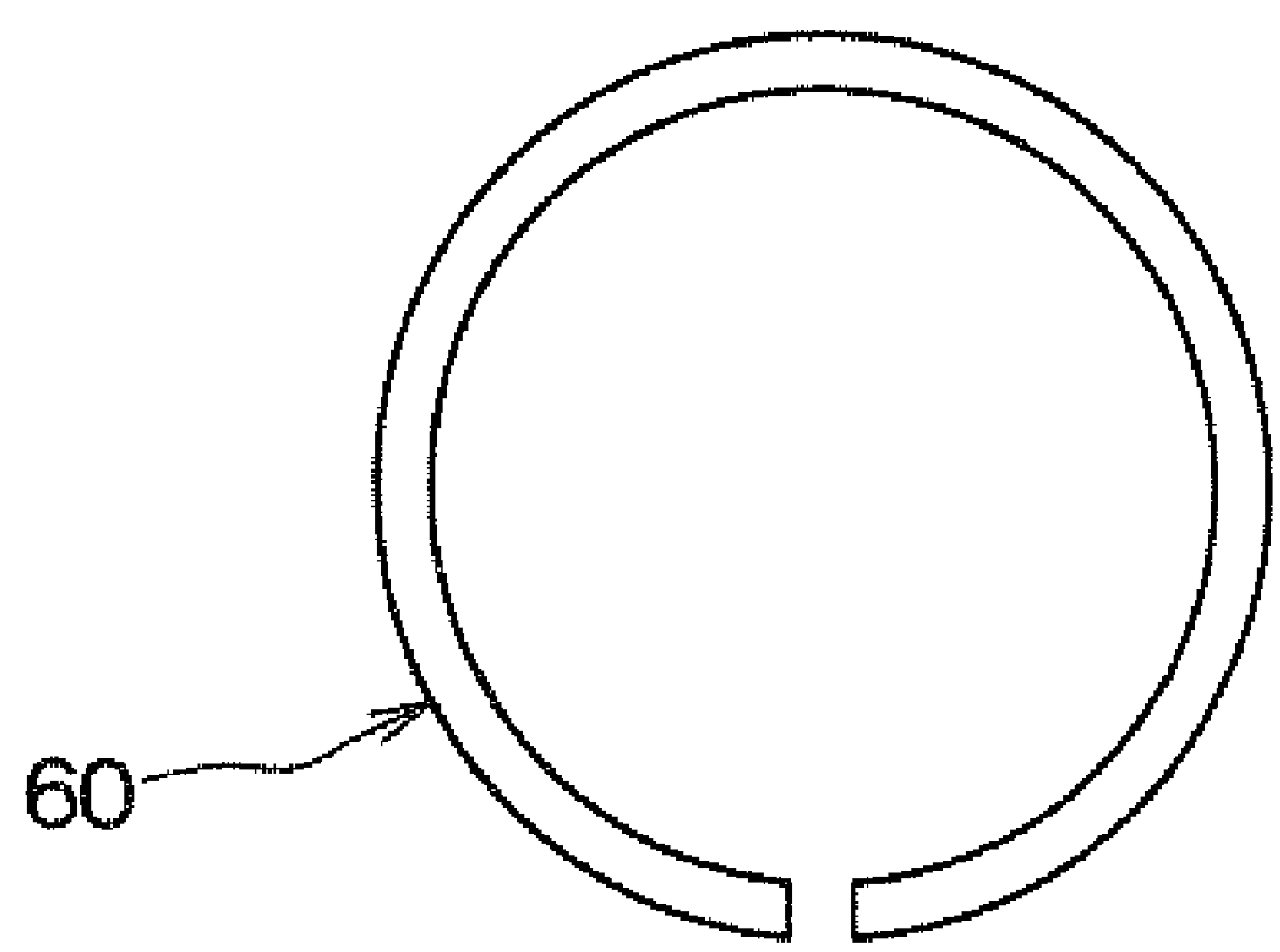

FIG. 7

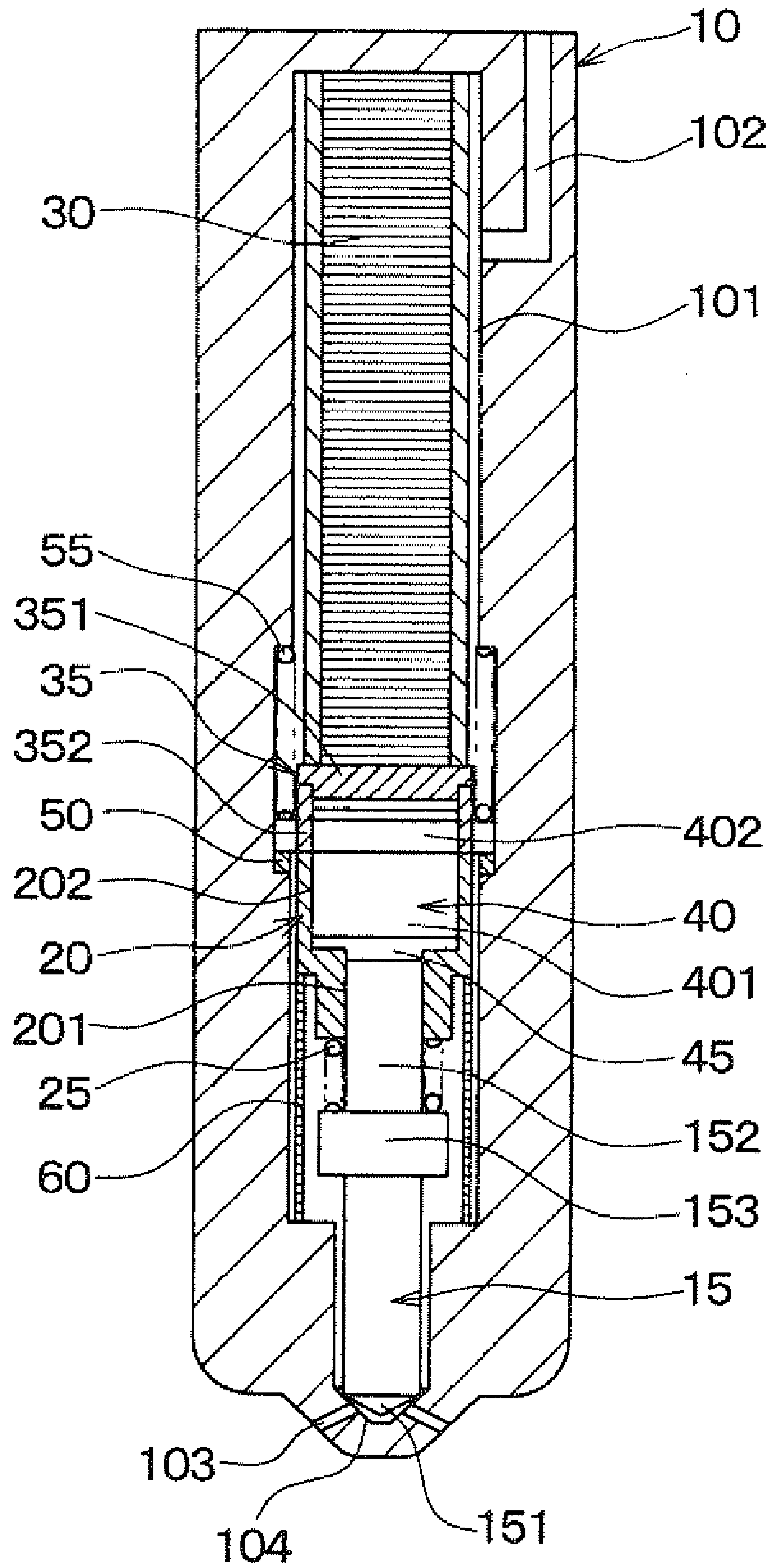
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FIG. 8

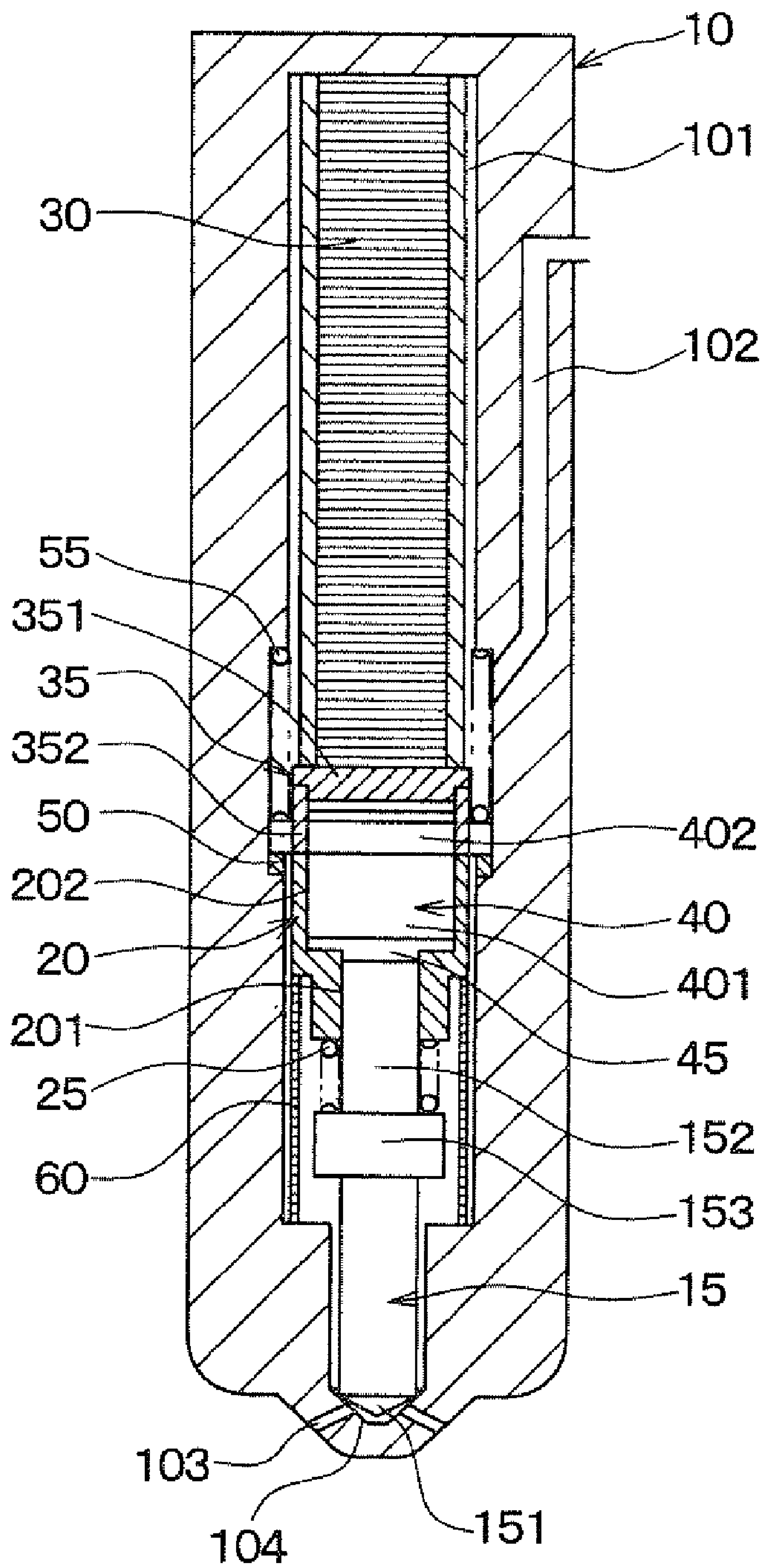
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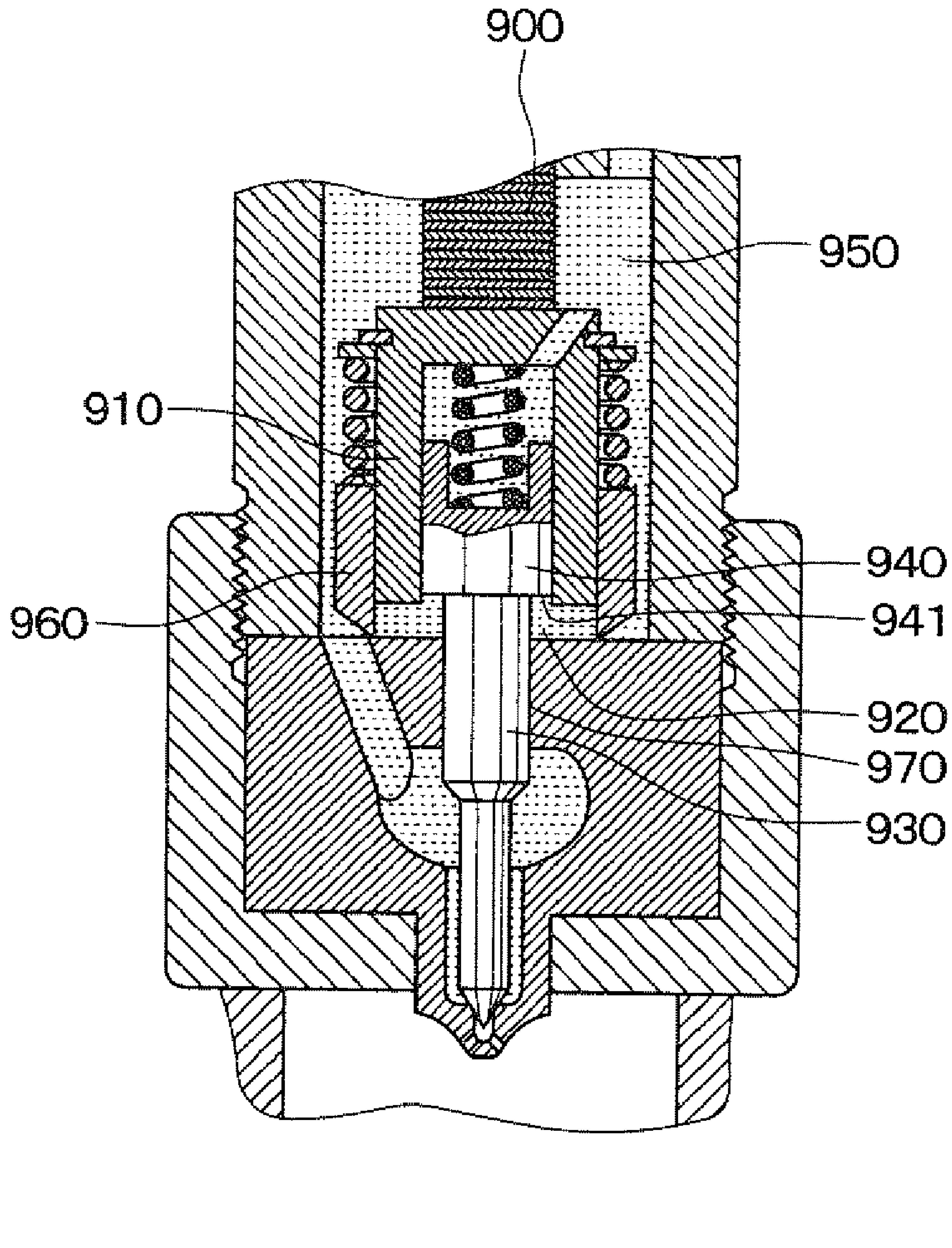
FIG. 9
PRIOR ART



FUEL INJECTION VALVE

CROSS REFERENCE TO RELATED APPLICATION

This application is based on and incorporates herein by reference Japanese Patent Application No. 2007-232379 filed on Sep. 7, 2007.

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to a fuel injection valve for injecting fuel into an internal combustion engine.

2. Description of Related Art

In a fuel injection valve shown in U.S. Pat. No. 6,420, 817B1, a valve closing operation is performed on a nozzle needle (i.e., the nozzle needle closes a nozzle hole) when a piezo stack is charged with electric charge to have a high voltage, and a valve opening operation is performed on the nozzle needle when the electric charge is discharged and thereby the piezo stack has a low voltage. In such a case, while an internal combustion engine is in operation, a period during which the piezo stack is at a high voltage is longer than a period during which the piezo stack is at a low voltage. Thus, the above fuel injection valve is not desirable in respect of reliability (e.g., durability) of the piezo stack.

Accordingly, a fuel injection valve, which is configured such that the valve opening operation is performed on the nozzle needle while the piezo stack is at a high voltage and the valve closing operation is performed on the nozzle needle while the piezo stack is at a low voltage, is proposed in, for example, JP-T-2007-500304 (corresponding to US2007/0152084A1).

As shown in FIG. **9**, in the fuel injection valve of JP-T-2007-500304, when a piezo stack **900** has a high voltage and is thereby extended, a first transfer piston **910** is driven, and accordingly a pressure of fuel in an oil-tight chamber **920** rises. A pressure of fuel in the oil-tight chamber **920** is applied to an annular surface **941** of a second transfer piston **940** formed integrally with a nozzle needle **930**, and as a result, the nozzle needle **930** opens a nozzle hole.

However, in the fuel injection valve of JP-T-2007-500304, there are three sliding portion clearances between a high pressure fuel passages **950**, through which high pressure fuel flows, and the oil-tight chambers **920**. Consequently, when the fuel injection valve is in the valve opening operation, an amount of fuel, which leaks out of the oil-tight chamber **920** to the high pressure fuel passage **950** through the above clearances, increases. In addition, the three sliding portion clearances are a clearance between the first transfer piston **910** and the second transfer piston **940**, a clearance between the first transfer piston **910** and a sleeve **960**, and a clearance between the nozzle needle **930** and a guide part **970**.

When the amount of fuel leaking out of the oil-tight chamber **920** to the high pressure fuel passage **950** increases, drive transmission efficiency is decreased. In the present specification, the decrease in the drive transmission efficiency means a decrease in an actual displacement enlargement factor (=a lift amount of a nozzle needle/a stretch amount of a piezo actuator).

When the amount of fuel leaking out of the oil-tight chamber **920** to the high pressure fuel passage **950** increases, the nozzle lift decreases and thus a spray state deteriorates in a late phase of the injection due to a pressure drop of the oil-tight chamber **920**, in the case of a long fuel injection period.

Furthermore, it is difficult to make large an area of the annular surface **941** of the second transfer piston **940**. Therefore, a differential pressure between the oil-tight chamber **920** and the high pressure fuel passage **950** needs to be made larger, in order that the nozzle needle **930** opens the nozzle hole.

As the differential pressure between the oil-tight chamber **920** and the high pressure fuel passage **950** becomes larger, the amount of fuel leaking out of the oil-tight chamber **920** to the high pressure fuel passage **950** increases. As a result, problems such as the decrease in the drive transmission efficiency and the deterioration of the spray state become more noticeable.

Additionally, in order to make large the differential pressure between the oil-tight chamber **920** and the high pressure fuel passage **950**, an extension amount of the piezo stack **900** needs to be increased for the fuel pressure of the oil-tight chamber **920** to be high enough. For this reason, charging energy supplied to the piezo stack **900** increases.

SUMMARY OF THE INVENTION

The present invention addresses the above disadvantages. Thus, it is an objective of the present invention to improve drive transmission efficiency while a fuel injection valve is in valve opening operation and to reduce charging energy supplied to a piezo stack. In the above fuel injection valve, a nozzle needle is operated to open a nozzle hole when a piezo stack has a high voltage.

To achieve the objective of the present invention, there is provided a fuel injection valve including a body, a nozzle needle, a piezo stack, a cylinder, a fixed piston, an oil-tight chamber, and a nozzle spring. The body has a high pressure fuel passage, through which high-pressure fuel flows, and a nozzle hole, which is connected to the high pressure fuel passage. The nozzle needle is disposed to open and close the nozzle hole and has a needle piston part. The piezo stack is configured to be extended when the piezo stack is charged with electric charge and is configured to be contracted when the piezo stack discharges the electric charge. The needle piston part of the nozzle needle is slidably inserted in the cylinder, and the cylinder is driven by the piezo stack. The fixed piston is fixed to the body and has a fixed piston part, which is slidably inserted in the cylinder. A diameter of the fixed piston part is larger than a diameter of the needle piston part. The oil-tight chamber is defined by the needle piston part and the fixed piston part and is located between the needle piston part and the fixed piston part in the cylinder. The nozzle spring is disposed to urge the nozzle needle in a direction in which the nozzle needle closes the nozzle hole. The cylinder is displaced as a result of the extension of the piezo stack, so that volume of the oil-tight chamber increases and thereby the nozzle needle opens the nozzle hole. The cylinder is displaced as a result of the contraction of the piezo stack, so that the volume of the oil-tight chamber decreases and thereby the nozzle needle closes the nozzle hole.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention, together with additional objectives, features and advantages thereof, will be best understood from the following description, the appended claims and the accompanying drawings in which:

FIG. **1** is a longitudinal sectional view illustrating a configuration of a fuel injection valve according to a first embodiment of the invention;

FIG. **2** is a schematic view illustrating a fixed piston in FIG. **1** viewed from a direction A;

FIG. **3**A is a front view illustrating a push plate in FIG. **1**;

FIG. **3**B is a bottom view illustrating the push plate;

FIG. **4**A is a front view illustrating a modified example of the push plate;

FIG. **4**B is a bottom view illustrating the modified example of the push plate;

FIG. **5** is a longitudinal sectional view illustrating a configuration of a fuel injection valve according to a second embodiment of the invention;

FIG. **6**A is a front view illustrating a piezo spring in FIG. **5**;

FIG. **6**B is a plan view illustrating the piezo spring;

FIG. **7** is a longitudinal sectional view illustrating a configuration of a fuel injection valve according to a third embodiment of the invention;

FIG. **8** is a longitudinal sectional view illustrating a configuration of a fuel injection valve according to a fourth embodiment of the invention; and

FIG. **9** is a longitudinal sectional view illustrating a configuration of a previously proposed fuel injection valve.

DETAILED DESCRIPTION OF THE INVENTION

First Embodiment

A first embodiment of the invention is described below.

A fuel injection valve is attached to a cylinder head of an internal combustion engine (more specifically a diesel engine: not shown), and injects high pressure fuel stored in a pressure accumulator (not shown) into a cylinder of the engine.

As shown in FIG. **1**, a receiving space **101** having a generally cylindrical shape, a high pressure fuel passage **102**, through which high pressure fuel supplied by the pressure accumulator flows, and a nozzle hole **103**, through which high pressure fuel is injected into the cylinder of the engine, are formed in a body **10** of the fuel injection valve having a generally cylindrical shape. The receiving space **101** extends along a axial direction (hereinafter referred to as a body axial direction) of the body **10**, in a central portion of the body **10** in a radial direction (hereinafter referred to as a body radial direction) of the body **10**. The high pressure fuel passage **102** is located outward of the receiving space **101** in the body radial direction, and extends along the body axial direction. The nozzle hole **103** is located one end of the body **10** in the body axial direction. The high pressure fuel passage **102** is connected to the receiving space **101** near a position, where a nozzle needle **15** (to be described in greater detail hereinafter) is disposed, and communicates with the nozzle hole **103** via the receiving space **101**. In addition, in the present specification, the receiving space **101** and the high pressure fuel passage **102** are collectively referred to as a high pressure fuel system **101**, **102**.

The nozzle needle **15**, which opens and closes the nozzle hole **103**, is slidably held by the body **10** in one end side (nozzle hole **103**-side) of the receiving space **101** in the body radial direction. More specifically, a tapered valve seat **104** is formed on the body **10** on an upstream side of the nozzle hole **103**, and the nozzle hole **103** is closed and opened when a seat part **151** formed on the nozzle needle **15** approaches or separates from the valve seat **104**.

A cylindrical needle piston part **152** is formed on the nozzle needle **15** on an opposite side of the nozzle needle **15** from the seat part **151**. The needle piston part **152** is slidably inserted in a cylinder **20** (to be described in greater detail hereinafter).

The nozzle needle **15** has a flanged portion **153** at its intermediate part in an axial direction of the needle **15**, and a nozzle spring **25** is arranged between the flanged portion **153** and the cylinder **20**. A compression coil spring is used for the nozzle spring **25**, and the nozzle needle **15** is urged in a valve closing direction by the nozzle spring **25**.

A piezo stack **30**, which includes many stacked piezoelectric elements and is expanded and contracted by the charge and discharge of electric charge, is received in the other end side (opposite side of the nozzle hole **103**) of the receiving space **101** in the body axial direction. A push plate **35** (to be described in greater detail hereinafter) is arranged between the piezo stack **30** and the cylinder **20**, and the cylinder **20** is driven by the piezo stack **30** through the push plate **35** when the piezo stack **30** is extended.

The cylinder **20** has a cylindrical shape with a step having a step portion on its inner circumferential surface. A columnar first cylinder hole **201** is formed on one side of the step portion, and a columnar second cylinder hole **202** having a larger diameter than the first cylinder hole **201** is formed on the other side of the step portion. The first cylinder hole **201** and the second cylinder hole **202** are arranged in series in the body axial direction, and more specifically, the first cylinder hole **201** is located further on the one end side in the body axial direction than the second cylinder hole **202**.

The needle piston part **152** is slidably inserted in the first cylinder hole **201**, and a columnar fixed piston part **401** formed in a fixed piston **40** is slidably inserted in the second cylinder hole **202**. The fixed piston part **401** has a larger diameter than the needle piston part **152**. Accordingly, volume of the oil-tight chamber **45** when the cylinder **20** is displaced due to the extension of the piezo stack **30** is increased.

In the cylinder **20**, a oil-tight chamber **45** is defined by the needle piston part **152** and the fixed piston parts **401** between the needle piston part **152** and the fixed piston parts **401**. The oil-tight chamber **45** communicates with the receiving space **101** through a clearance between the first cylinder hole **201** and the needle piston part **152** and a clearance between the second cylinder hole **202** and the fixed piston part **401**.

As shown in FIG. **2**, the fixed piston **40** has a flanged portion **402**, which projects radially outward from the fixed piston part **401**. The flanged portion **402** is divided into three pieces along its circumferential direction, and a notch section **403** is formed between two adjacent flanged portions **402**. As shown in FIG. **1**, the flanged portion **402** is held between a cylindrical spacer **50** and a fixed spring **55** and thereby the fixed piston **40** is fixed to the body **10**.

As shown in FIGS. **3**A, **3**B, the push plate **35** has a columnar disk part **351** and a columnar leg **352**, which projects in an axial direction of the disk part **351** from one end surface of the disk part **351**. There are three legs **352** along a circumferential direction of the disk part **351**, and each of the three legs **352** is inserted in the corresponding notch section **403** of the fixed piston **40** (see FIG. **2**). As shown in FIG. **1**, the disk part **351** of the push plate **35** in contact with the piezo stack **30**, and the leg **352** of the push plate **35** is in contact with the cylinder **20**.

Additionally, a push plate **35** shown in FIGS. **4**A, **4**B may be used for the push plate **35**. As shown in FIGS. **4**A, **4**B, a leg **352** of the push plate **35** may be formed in a generally prismatic column.

Workings of the fuel injection valve are explained below. FIG. **1** shows a valve closing state of the fuel injection valve. In the above state, high pressure fuel flows into the oil-tight chamber **45** from the receiving space **101** through the clearance between the first cylinder hole **201** and the needle piston part **152** and the clearance between the second cylinder hole

202 and the fixed piston part **401**, and as a result, a pressure of the oil-tight chamber **45** is equal to a pressure of the high pressure fuel system **101**, **102**. The nozzle needle **15** is urged in the valve closing direction by a pressure of the oil-tight chamber **45** applied to the needle piston part **152**, and is urged in the valve closing direction by the nozzle spring **25** to be in the valve closing state.

When a charging current is supplied to the piezo stack **30** (i.e., the piezo stack **30** is charged with an electric charge) and thereby a piezo voltage increases, the piezo stack **30** is extended. Accordingly, the cylinder **20** is driven from the other end side toward the one end side in the body axial direction via the push plate **35** and thereby the volume of the oil-tight chamber **45** is expanded. Consequently, the pressure of the oil-tight chamber **45** decreases and thus force, which urges the nozzle needle **15** in the valve closing direction, decreases. Therefore, the nozzle needle **15** is displaced in a valve opening direction, and the seat part **151** disengages from the valve seat **104** so as to open the nozzle hole **103**. As a result, fuel is injected into the cylinder of the engine through the nozzle hole **103**.

After that, when the electric charge is discharged from the piezo stack **30** and thereby the piezo voltage falls, the piezo stack **30** is contracted. Accordingly, the cylinder **20** is returned toward the piezo stack **30** by the nozzle spring **25**, and thereby the volume of the oil-tight chamber **45** is reduced. Consequently, the pressure of the oil-tight chamber **45** rises and thus the force, which urges the nozzle needle **15** in the valve closing direction, increases. Therefore, the nozzle needle **15** is displaced in the valve closing direction, and the seat part **151** engages the valve seat **104** so as to close the nozzle hole **103**. As a result, the fuel injection is ended.

In the fuel injection valve of the first embodiment, a sliding portion clearance between the oil-tight chamber **45** and the receiving space **101** includes two areas, that is, the clearance between the first cylinder hole **201** and the needle piston part **152** and the clearance between the second cylinder hole **202** and the fixed piston part **401**. Thus, an amount of fuel, which leaks into the oil-tight chamber **45** from the receiving space **101** through the above clearances when the fuel injection valve is in valve opening operation, decreases, so that drive transmission efficiency is improved.

Moreover, as will be described below, according to the fuel injection valve of the first embodiment, a differential pressure between the oil-tight chamber **45** and the high pressure fuel system **101**, **102** is made small.

In the fuel injection valve shown in JP-T-2007-500304, it is assumed that an outer diameter (i.e., outer diameter of the oil-tight chamber **920**) of the first transfer piston **910** is A, an outer diameter (i.e., outer diameter of the annular surface **941**) of the second transfer piston **940** is B, an outer diameter (i.e., inner diameter of the annular surface **941**) of a portion of the nozzle needle **930** held by the guide part **970** is C, and a displacement enlargement factor is K1. In addition, K1 is equal to $(A^2-B^2)/(B^2-C^2)$.

In the fuel injection valve of the first embodiment, it is assumed that an outer diameter of the fixed piston part **401** is D, an outer diameter of the needle piston part **152** is E, and a displacement enlargement factor is K2. In addition, K2 is equal to $(D^2-E^2)/E^2$.

Given that A is D, K1 is K2, and C is larger than 0 (zero), an expression $B^2-C^2<E^2$ is satisfied. Therefore, a cross-sectional area of the needle piston part **152** of the fuel injection valve of the first embodiment is larger than an area of the annular surface **941** of the fuel injection valve of JP-T-2007-500304.

Accordingly, in the fuel injection valve of the first embodiment, the differential pressure between the oil-tight chamber **45** and the high pressure fuel system **101**, **102** is made smaller than in the fuel injection valve of JP-T-2007-500304. As a result, an amount of fuel, which leaks from the high pressure fuel system **101**, **102** into the oil-tight chamber **45** when the fuel injection valve is in valve opening operation, is made smaller and thereby the drive transmission efficiency is improved. Furthermore, corresponding to reduction in the leaking amount, an extension amount of the piezo stack **30** can be set at a small value. Consequently, charging energy supplied to the piezo stack **30** can be reduced.

In the first embodiment, the high pressure fuel passage **102** is connected to the receiving space **101** near the position at which the nozzle needle **15** is arranged, in other words, the high pressure fuel passage **102** extends close to the nozzle hole **103**. Accordingly, a pressure drop is small and a good fuel spray is achieved.

Second Embodiment

A second embodiment of the invention is explained below. The same numerals as those used in the first embodiment are used for components, which are the same as or equivalent to the components of the first embodiment, and their descriptions are omitted.

As shown in FIG. **5**, in a fuel injection valve of the second embodiment, a piezo spring **60** is arranged between a body **10** and a cylinder **20**. The piezo spring **60** urges the cylinder **20** in a direction in which volume of an oil-tight chamber **45** reduces.

Accordingly, when the electric charge is discharged from a piezo stack **30** and thereby the piezo voltage falls, the cylinder **20** is returned toward the piezo stack **30** by a nozzle spring **25** and the piezo spring **60**. Therefore, a response of the fuel injection valve in closing a nozzle hole **103** is improved.

Also, because a load of the piezo spring **60** is not applied to a nozzle needle **15**, the fuel injection valve has a high degree of flexibility in setting a spring constant of the piezo spring **60**. Therefore, by setting the spring constant of the piezo spring **60** at a large value, the response of the fuel injection valve in closing the nozzle hole **103** is further improved.

As shown in FIGS. **6**A, **6**B, the piezo spring **60** employs a slit spring, which is formed as a result of forming a metal plate material having many holes **601** in a staggered manner to have a cylindrical shape. Using the slit spring, a spring having a large spring constant is easily obtained.

Third Embodiment

A third embodiment of the invention is explained below. In the third embodiment, a position where a high pressure fuel passage **102** is connected to a receiving space **101** is different from the second embodiment. The same numerals as those used in the second embodiment are used for components, which are the same as or equivalent to the components of the second embodiment, and their descriptions are omitted.

As shown in FIG. **7**, in a fuel injection valve of the third embodiment, the high pressure fuel passage **102** is connected to the receiving space **101** near the other end side of a receiving space **101** in a body axial direction. Accordingly, the high pressure fuel passage **102** does not need to be located near a side surface of the body **10**. Thus, reliability (internal-pressure strength) of the fuel injection valve is improved, and a diameter of the receiving space **101** is made large. By making larger the diameter of the receiving space **101**, the fuel injection valve has a higher degree of flexibility in designing components, which are received in the receiving space **101**.

Fourth Embodiment

A fourth embodiment of the invention is described below. In the fourth embodiment, a position where a high pressure fuel passage **102** is connected to a receiving space **101** is different from the second embodiment. The same numerals as those used in the second embodiment are used for components, which are the same as or equivalent to the components of the second embodiment, and their descriptions are omitted.

As shown in FIG. **8**, in a fuel injection valve of the fourth embodiment, the high pressure fuel passage **102** is connected to the receiving space **101** near one end side of a piezo stack **30** in a body axial direction. Accordingly, the pressure drop is lessened and reliability (internal-pressure strength) is improved. Furthermore, the fuel injection valve has a high degree of flexibility in designing components received by the receiving space **101** other than the piezo stack **30**.

Additional advantages and modifications will readily occur to those skilled in the art. The invention in its broader terms is therefore not limited to the specific details, representative apparatus, and illustrative examples shown and described.

What is claimed is:

1. A fuel injection valve comprising:

a body having a high pressure fuel passage, through which high-pressure fuel flows, and a nozzle hole, which is connected to the high pressure fuel passage;

a nozzle needle disposed to open and close the nozzle hole and having a needle piston part;

a piezo stack configured to be extended when the piezo stack is charged with electric charge and configured to be contracted when the piezo stack discharges the electric charge;

a cylinder, in which the needle piston part of the nozzle needle is slidably inserted and which is driven by the piezo stack;

a fixed piston fixed to the body and having a fixed piston part, which is slidably inserted in the cylinder, wherein a diameter of the fixed piston part is larger than a diameter of the needle piston part;

an oil-tight chamber defined by the needle piston part and the fixed piston part and located between the needle piston part and the fixed piston part in the cylinder; and

a nozzle spring disposed to urge the nozzle needle in a direction in which the nozzle needle closes the nozzle hole, wherein:

the cylinder is displaced as a result of the extension of the piezo stack, so that volume of the oil-tight chamber increases and thereby the nozzle needle opens the nozzle hole; and

the cylinder is displaced as a result of the contraction of the piezo stack, so that the volume of the oil-tight chamber decreases and thereby the nozzle needle closes the nozzle hole.

2. The fuel injection valve according to claim **1**, wherein the oil-tight chamber communicates with the high pressure fuel passage through a clearance between the cylinder and the needle piston part and a clearance between the cylinder and the fixed piston part.

3. The fuel injection valve according to claim **1**, wherein the nozzle spring is held between the nozzle needle and the cylinder to urge the cylinder in a direction in which the volume of the oil-tight chamber decreases.

4. The fuel injection valve according to claim **1**, further comprising a piezo spring configured to urge the cylinder in a direction in which the volume of the oil-tight chamber decreases.

5. The fuel injection valve according to claim **4**, wherein the piezo spring is a slit spring, which is obtained as a result of forming a metal plate material having many holes into a cylindrical shape.

6. The fuel injection valve according to claim **1**, wherein:

the cylinder has a step portion on an inner circumferential surface of the cylinder;

the cylinder includes a first cylinder hole, in which the needle piston part is inserted, on one side of the step portion in an axial direction of the cylinder, and a second cylinder hole, in which the fixed piston part is inserted, on the other side of the step portion in the axial direction; and

a diameter of the second cylinder hole is larger than a diameter of the first cylinder hole.

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